crystalline, and is adherent to the sand grains in such a way as to show that it has been deposited *in situ* subsequently to the sand grains. Mr. Lomas states that the occurrence of barytes in the trias is fairly common, and mentions the following localities, in which its presence is well known:—Beeston, Alderley Edge, Oxton, Storeton, and Peakstones Rock, Alton. The sulphate is also stated to occur at West Kirby, in Cheshire, and elsewhere as a joint filling, the joints often standing out from the surface of the rock, owing to the resistance of the sulphate to weathering.]

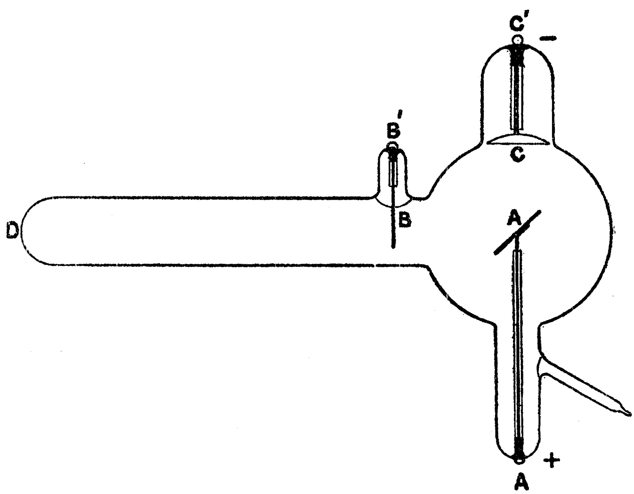
"On the Reflection of Cathode Rays." By A. A. CAMPBELL SWINTON. Communicated by LORD KELVIN, F.R.S. Received January 25,—Read February 9, 1899.

Preliminary.

There being apparently some doubt as to the exact nature of the rays, named by Professor S. P. Thompson paracathodic rays,* which in a Crookes tube of the focus type proceed from the front surface of the anti-cathode, and cause the green fluorescence of the glass, the writer has made the following investigations:—

Firstly, in order to determine the magnetic deflectibility of the paracathodic rays, a tube was constructed as shown in fig. 1, in which C is the cathode, A the anti-cathode and anode, and B an aluminium wire

FIG. 1.



* 'Phil. Trans.,' vol. 190, pp. 480—483.

sealed into the glass of an elongated annex. The tube was exhausted to about 0·000005 atmosphere, and the arrangement was such that the paracathodic rays proceeding from A, cast a sharp shadow of B upon the glass at D. The distance from B to D was made long so that a small horse-shoe magnet, held so as to embrace the annex between B and D, would deflect the paracathodic rays without materially affecting the cathode rays passing from C to A. With this arrangement it was found that the shadow of B, cast by the paracathodic rays, was always moved by the magnet in the same direction as it would have been moved had it been cast by cathode rays proceeding from A, thus showing that paracathodic rays are magnetically deflected in the same direction as cathode rays.

This would point to the paracathodic rays consisting of negatively charged particles, as does also the fact, noted by Professor S. P. Thompson, with a somewhat similar tube, and confirmed by the writer, that when the wire B is positively or negatively charged from a separate electrical source, the consequent contraction or enlargement of its shadow at D denotes electro-static attraction or repulsion between B and the rays.

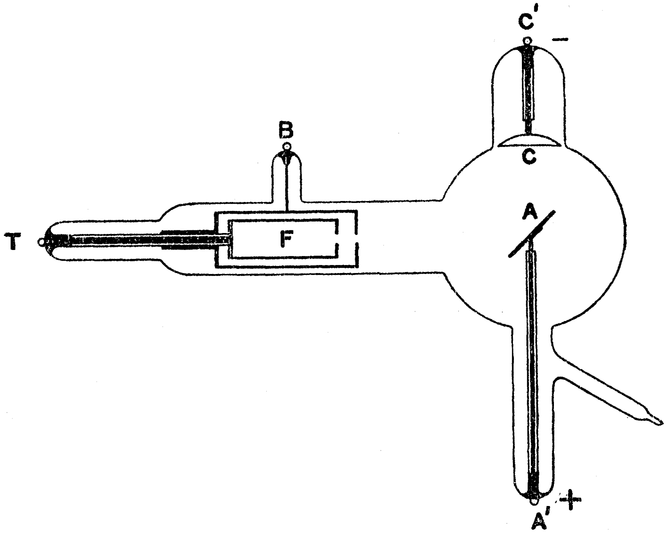
However, as previously noted by the writer,* an exploring pole immersed in the paracathodic rays, acquires a positive charge, and the wire B in the tube illustrated in fig. 1, was found invariably to have a slight positive charge, if tested with an electroscope when the tube was being used as in the first experiment described above. On the other hand, it was found that when the wire B was used as anode instead of A, the latter also acquired a positive charge, though directly played upon by the cathode rays.

It was therefore decided to determine the nature of the electrification of the paracathodic rays by means of the Faraday cylinder method employed by Perrin for testing cathode rays. It is generally agreed that this method gives more conclusive results than those obtained with exploring poles, where the effects of induction and possibly other causes appear to introduce errors.

A tube was therefore constructed as shown in fig. 2, in which C is the cathode and A is both anode and anti-cathode; F is the Faraday cylinder of brass, pierced by a small aperture through which the paracathodic rays from A can enter, and connected by means of a wire entirely enclosed in glass, with the terminal T. The Faraday cylinder is enclosed in another coaxial brass cylinder, also having an aperture facing the anticathode, and connected with the terminal B, which during the experiments was connected to earth, so as to screen the Faraday cylinder from outside influence. The Faraday cylinder was connected through T with the leaves of an electroscope, and when the tube was put into action and the paracathodic rays entered the cylinder,

* 'Roy. Soc. Proc.,' vol. 63, 1898, pp. 436—437.

FIG. 2.



it was found that the gold leaves invariably diverged with a negative charge. The divergence of the leaves was increased by connecting A to earth, and when a horse-shoe magnet was held so as to deflect the paracathodic rays, and prevent them from entering the Faraday cylinder, the closing together of the leaves showed that the cylinder no longer received any charge at all.

These experiments appear to show conclusively both that paracathodic rays are deflected magnetically in the same way as cathode rays, and also that they behave similarly to the latter in conveying a negative charge. In addition they cause green fluorescence of the glass upon which they fall, and as the writer has already shown,* they also generate Röntgen rays where they impinge upon a solid body.

Paracathodic rays appear therefore to be simply reflected cathode rays.

The Mechanical Force Exerted by Reflected Cathode Rays.

These reflected cathode rays appear however to be relatively of very feeble intensity. The amount of Röntgen rays that they generate where they strike the glass is very small; while, so far as the writer has been able to ascertain, they exert no appreciable mechanical force on the most delicately arranged radiometer mill wheels.

At one time it seemed possible that reflected cathode rays might be the cause of the inverse rotation of mill wheels placed just outside of

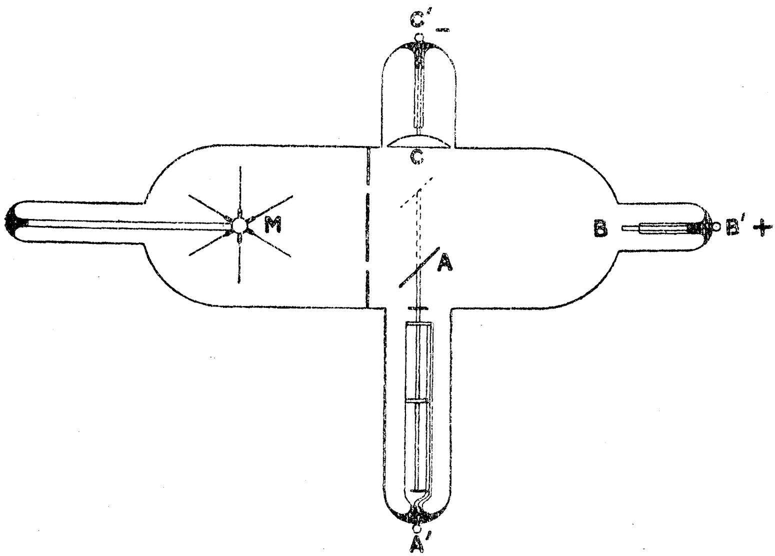
* 'Roy. Soc. Proc.,' vol. 63, 1898, pp. 436—437.

the cathode stream, described recently by the writer in two papers to the Physical Society.*

For the purpose of testing this, several experiments were made. Firstly, a tube was constructed in which the anticathode was mounted on an axis, so that by rotating it through a small angle the cathode rays could be reflected on to one side or the other of a very delicately pivoted mill wheel with mica vanes. That the rays were so reflected was apparent from the fluorescence of the glass and the shadows cast by the vanes, but the rotations of the wheel were quite inconclusive, and did not appear to have any definite relation to the direction of the reflected cathode rays.

The tube shown in fig. 3 was next constructed. In this tube there is a diaphragm of mica, that divides the tube into two portions. One portion contains the six-vaned mill wheel M, and the other the

FIG. 3.



cathode C, and an inclined anticathode A. The diaphragm is pierced with two oblong apertures, and the anticathode arranged on a sliding stem so that it can be placed to reflect the cathode rays through one or other aperture on to one side or the other of the wheel as desired. When exhausted and connected either to an induction coil or influence machine, the reflected cathode rays from A in either position passing through the corresponding aperture in the diaphragm, gave a distinct patch of

* 'Phil. Mag.,' October, 1898, pp. 387—395.

fluorescence on the glass beyond, throwing upon the latter a well-defined shadow of the vanes of the mill wheel. Under these conditions the wheel was found to rotate, but not in the direction anticipated; in fact, for either position of the anticathode the direction of rotation was most persistently opposite to what would be expected on the supposition that the driving force was the impact of the reflected rays. When the position of the anticathode was suddenly moved so as to reflect the rays first through one aperture and then through the other, the direction of rotation immediately reversed itself, the direction of rotation being always as though there was some attractive force between the anticathode and the particular vanes upon which the reflected rays were at the moment falling.

These and further experiments, made with another arrangement in which instead of a single bulb divided by a mica diaphragm, two separate bulbs were used, one containing the cathode and anticathode and the other the mill wheel, united by a pair of glass tubes corresponding to the apertures in the mica, appear to show that whatever may be the cause of the inverse rotation of mill wheels which are not directly acted upon by cathode rays, this is not due to the direct mechanical force exerted by the impact of reflected cathode rays, but to some other force or forces of a much more potent nature.

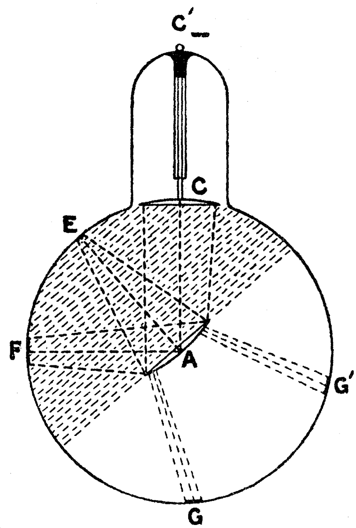
The Mode of Reflection of Cathode Rays.

The reflection of cathode rays is largely diffuse, but does not appear to be altogether so, as the writer has already pointed out,* and since more completely verified by the following further investigations.

In the first place, experiments were made to see whether any direct visual evidence of specular reflection of cathode rays could be obtained with a spherically concave reflector. For this purpose the tube shown in fig. 4 was constructed. In this tube the cathode C is made of aluminium 1·25 inches diameter, and is spherically concave on its active surface with a curvature of a 10-inch sphere, so as to give a fairly parallel beam of cathode rays. The anti-cathode A consists of a circular disc of platinum about 0·9 inch diameter, stamped into a mould having a curvature equal to that of a 10-inch sphere, the concave surface of the platinum being highly polished. The anti-cathode is mounted on a vertical spindle, arranged in guides, and furnished with a small brass bob weight attached to a horizontal arm, so that by tapping the tube the anti-cathode can be rotated round its vertical axis into any desired position. The diameter of the spherical bulb, at the centre of which the anti-cathode is placed, is 3·6 inches, and an additional wire electrode is provided in an annex at the top to serve as anode. In experimenting with this tube, a 10-inch induction coil, with

* 'Roy. Soc. Proc.,' vol. 63, p. 436.

Fig. 4.



mercury contact breaker, working at about one-half full power, was employed, and when this coil was connected through two spark gaps to the cathode C and the spare anode, the anti-cathode A being connected to earth, the following phenomena were observed.

With the anti-cathode so placed, as shown in fig. 4, that the cathode rays impinged on its concave side at an average angle of about 135°, in addition to the slight general green fluorescence of about half the bulb, due to the diffuse reflection of the incident cathode rays by the concave anti-cathode, which fluorescence, as indicated in the illustration, did not differ from what is usually observed in focus tubes, there appeared two very bright and somewhat unstable fluorescent patches upon the glass of the bulb facing the concave side of the anti-cathode. One of these patches, E, which was approximately of circular form, was directly opposite the concave side of the anti-cathode, and was connected to the latter by a faintly luminous beam, while the other, F, which was of a horizontally elongated form, had a position corresponding with the extremity of a second luminous beam apparently of cathode rays reflected from the anti-cathode in true specular fashion. Further, on the glass facing the convex side of the anti-cathode, there at the same time appeared a large-diameter hollow ring of very faint fluorescence, GG′.

On slightly rotating the anti-cathode in either direction, both the patches and the ring were also found to move, the circular patch E, and the ring GG′, maintaining a position respectively exactly in front

of and behind the anti-cathode, while the elongated patch, F, moved to an extent that showed that the angular displacement of the reflected beam of cathode rays that occasioned it was twice the angular displacement of the reflecting surface.

The patch E, and the ring GG′, appear to be due to some description of rays given off directly by the anti-cathode normally to its concave and convex surfaces respectively, and independently of the position of the anti-cathode on its axis. The exact nature of these normal anti-cathode rays at present appears uncertain, and calls for further investigation.

The fluorescent patch F, from the manner in which both its movements and form obey the usual laws of reflection, seems undoubtedly to be due to cathode rays proceeding initially from the cathode C, and reflected specularly by the concave surface of the anti-cathode.

It should be mentioned that though, when obtained, the fluorescent patches described above are most distinct and unmistakable, they are not always obtained very readily. With the tube used, the patches increased in brightness when the spark gap included in the circuit between the coil and the anode of the tube was made fairly large. The patch F was best obtained when the angle between the incident and reflected beams is greater than 90° and less than 180°. This patch could not be obtained satisfactorily when the angle was much less than 90°, possibly owing to the incident beam interfering with the reflected beam. In order to obtain satisfactory patches, it was found that the anti-cathode must not be used as anode, and must be connected to earth; that there must be at least one spark-gap in the circuit, and that the anode must not be connected to earth. The patches are generally somewhat unsteady as regards position, being apparently affected by the varying electrification of the glass walls of the tube.

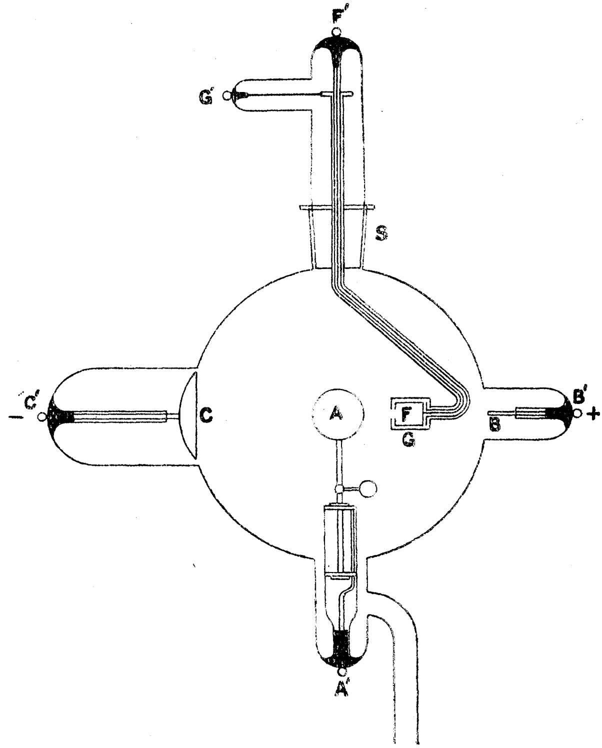
The patches were best obtained with the tube exhausted to about 0·000024 atmosphere, when the general green fluorescence over half the bulb, due to diffusely reflected cathode rays, was but faintly visible. When the degree of exhaustion was raised above that stated, the patches became larger and fainter, and finally disappeared, merging in the general fluorescence.

Quantitative Results.

Endeavours were next made to obtain accurate quantitative measurements of the cathode rays reflected from a flat and highly polished platinum surface by catching a definite portion of the reflected rays in a movable Faraday cylinder connected to earth through a galvanometer, and noting the amount of charge imparted to the cylinder for different angles both of incidence and reflection.

The first tube constructed for this purpose is shown in fig. 5. Here

Fig. 5.



the spherically concave cathode C is 1·25 inch diameter and 0·75 inch radius of curvature. A is the anti-cathode reflector, consisting of a plain disc of polished platinum 0·5 inch diameter, mounted on a vertical axis held in guides, and provided with a small bob weight, so that by tapping the tube, the reflector can be set in the position necessary to give any desired angle between its surface and the incident cathode rays. The electrode B is provided for use as anode. The Faraday cylinder is constructed with an inner and outer cylinder of brass, F and G, similar to those described in connection with fig. 2. The apertures into both cylinders are about 0·08 inch diameter. The cylinder is carried by a curved arm of glass tube, fixed to the glass stopper S, which is very carefully ground into the neck of the tube; a copper wire passing through the tubular arm serves to connect the inner Faraday cylinder with the terminal F′, while a thick coating of copper electrolytically deposited over the entire outside surface of the glass arm, and connected at one end to the outside Faraday cylinder G, and at the other end to the terminal G′, can be earthed and serves to

screen the inner cylinder and its connection from all outside influence. The experiments were conducted with the tube connected to the mercury pump, and the ground-glass stopper S being lubricated with a little vaseline was found to maintain the vacuum very well for considerable periods, while at the same time permitting of easy rotation of the Faraday cylinder round A into any desired position without the vacuum being impaired. A circular scale of cardboard attached to the tube around the neck near S, allowed of the angles made by the surface of A and the axis of the cylinder F with the axis of the cathode stream proceeding from C being accurately determined. The cathode C and the anode B were directly connected, without spark gaps, to a 10-inch Ruhmkorff coil with mercury contact breaker, working at about $\frac{1}{4}$ full power. The reflector A, as also the terminal G′, were joined up to an earth connection which special tests had shown to be efficient, while the inner Faraday cylinder was connected by means of F′ also to earth through a D'Arsonval mirror galvanometer, having 250 turns of wire in its coil. The tube was connected with a mercury pump, and also with a McLeod gauge. Even after prolonged exhaustion, it was found that much electrical power could not be applied to the tube for any length of time without largely deteriorating the vacuum, but with less power the latter was more constant. Even then the vacuum was found always to be slightly lower at the end of a series of observations than at the beginning, and in order to avoid this disturbing factor, every series was taken first one way and then again in reverse order, the mean of the two sets giving results from which the influence of the gradual decrease in the degree of exhaustion was very nearly eliminated.

Fig. 6.

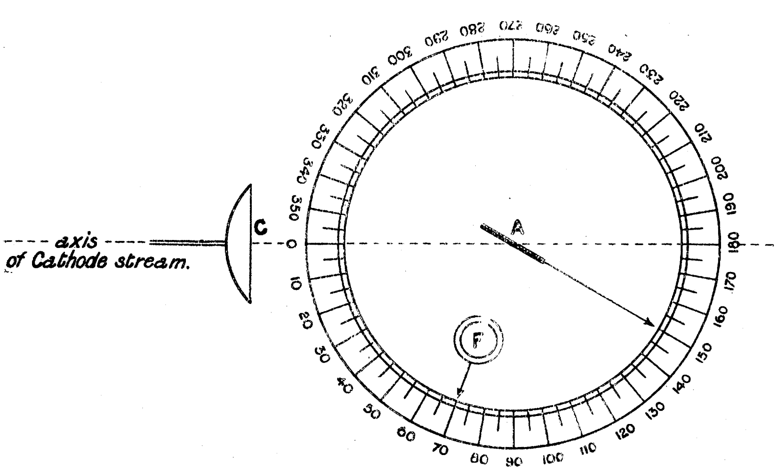


Fig. 6 shows the arrangement of the scale, from which the positions of the reflector and the Faraday cylinder relatively to the axis of the primary cathode stream can be seen for each observation in the following tables. The observed galvanometer deflections are in degrees of an arbitrary scale.

The first experiments were made with the Faraday cylinder stationary, the anti-cathode reflector being rotated; a specimen set of the results obtained is given in Table I.

Table I.

Faraday cylinder fixed at 90°.
Readings taken with reflector at different angles from 75° to 175°.
Pressure 0·000018 to 0·000023 atmosphere.

Reflector.	First series deflection.	Second series deflection.	Mean deflection.
75°	0·25	0·3	0·275
90	0·35	0·5	0·425
100	0·75	1	0·875
110	1·5	1·75	1·625
120	2·2	3	2·6
130	3	3·3	3·15
140	3·3	3·3	3·3
150	3	3·1	3·05
160	2·7	2·6	2·65
170	1·6	2	1·8
175	0·4	0·5	0·45

It will be observed that as the reflector was rotated the galvanometer deflections gradually increased in value up to a certain point, and then decreased again; also that the maximum mean deflection was obtained with the reflector at 140°, *i.e.*, very nearly at that position which would give equal angles of incidence and reflection for the cathode rays.

Next, the reflector was kept stationary, and the cylinder moved so as to explore the field of reflected rays. A specimen set of the results thus obtained is given in Table II.

In this instance, on the assumption of partial specular reflection, the maximum galvanometer deflection should of course be obtained with the cylinder as near to 0° as it could be placed without interfering with the primary cathode rays. It was not found practicable to place it nearer than 45°, but, as will be observed, the deflections rise steadily up to this latter position.

Several other series of observations were made with this tube, with the cylinder stationary at 45° and at 130°, with the reflector at varying angles, and also with the reflector stationary at 70° and at 135°, and

Table II.

Reflector fixed at 90°.
Readings taken with the Faraday cylinder at different positions from 95° to 45°.
Pressure 0·00001 to 0·000015 atmosphere.

Cylinder.	First series deflection.	Second series deflection.	Mean deflection.
95°	0·3	0·2	0·25
85	0·6	0·5	0·55
75	1	1·1	1·05
65	1·1	1·4	1·25
55	1·4	1·6	1·5
45	1·7	1·7	1·7

with the cylinder in various positions. In all instances a maximum deflection was obtained with positions that made the angles of incidence and reflection approximately equal, and smaller and smaller deflections resulted the further this position was departed from. However, as more accurate readings were afterwards obtained with another tube and more delicate arrangements, described below, it has been thought best to omit detailed particulars of these observations.

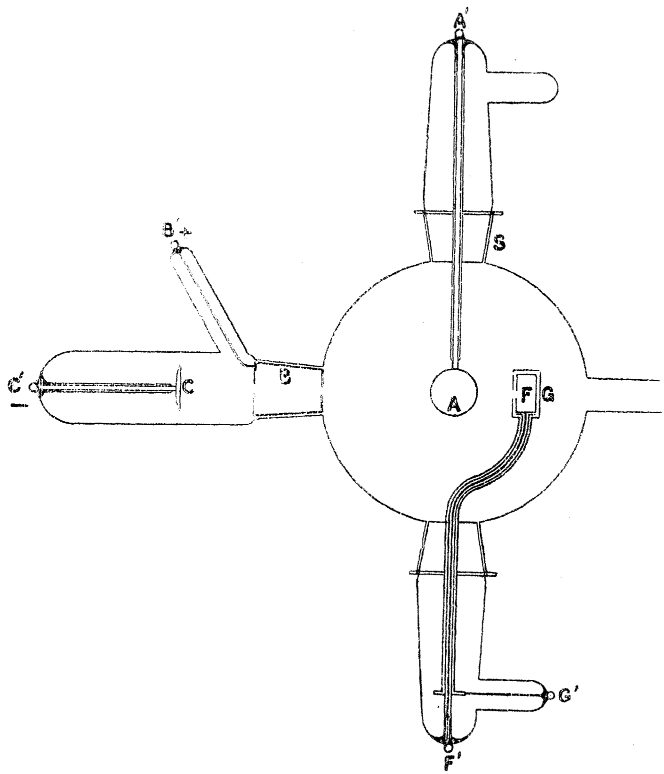
The above have, however, been mentioned to show that two tubes of different descriptions gave similar results, and also that the galvanometer method of measuring the charge imparted to the Faraday cylinder, as described above, gave similar results as the quadrant electrometer used in the further experiments.

The new tube with which experiments were next proceeded with is shown in fig. 7. The arrangements for rotating the reflector in the previous tube having been found somewhat unsatisfactory, in the new tube both the reflector and the Faraday cylinder were attached to ground stoppers, and furnished with pointers and scales, as in fig. 6, so that the angles could be adjusted with great nicety. Further, in order to obtain greater parallelism in the primary cathode stream, an arrangement of cathode and anode was adopted similar to that used by Professor J. J. Thomson.* According to this arrangement the cathode rays from C are directed through two apertures about 0·1 inch diameter in the hollow brass cylinder B, which is ground into a glass neck, and by means of the terminal B′ is used as anode.

It being found that the employment of little electric power was conducive to the maintenance of a constant vacuum, a 6-inch Ruhmkorff coil was substituted for the larger one used previously, and as with the diminished power, and with the very attenuated beam of cathode rays

* 'The Discharge of Electricity through Gases,' by J. J. Thomson, pp. 152 and 164.

Fig. 7.



that could pass through the small apertures in B, the D'Arsonval galvanometer would not give satisfactory readings even when a coil with 500 turns was used, a reflecting quadrant electrometer was employed instead. The needle of this electrometer was connected to the inner Faraday cylinder F by means of an insulated wire threaded through a lead pipe connected to earth so as to exclude all outside influence, and the electrometer was otherwise connected up according to Mascart's method. The deposition of moisture upon the tube being found to affect the results, incandescent electric lamps were arranged so as to keep the whole at a uniform temperature slightly above that of the surrounding atmosphere. In the subsequent experiments the anode B was always connected to earth.

In the following tables each unit of the number given as the deflection of the electrometer corresponds to a mean pressure of about 3 volts, though very probably, owing to the intermittent nature of the discharge, the actual instantaneous value was much higher. In each case the readings of the second series of observations were taken in

reverse order to those of the first series, and P, the pressure given in millionths of an atmosphere, was obtained by the McLeod gauge at the commencement and end of each series. Deflections indicating a positive charge given to the Faraday cylinder are so marked; all others denote negative charges.

Table III.

Faraday cylinder fixed at 45°.
Readings taken with Reflector at different angles from 45° to 180°.

Reflector.	First series deflection.	Second series deflection.	Mean deflection.
	P = 41	P = 54	
45°	0	0	0
50	0	0·5	0·25
55	2	1	1·5
60	2	1·5	1·75
65	4·5	3	3·75
70	8·5	7	7·75
75	15	13	14
80	20·5	18	19·25
85	24	21	22·5
90	25	25	25
95	27·5	27	27·25
100	29	30	29·5
105	29·5	32	30·75
110	30·5	33	31·75
115	31	34	32·5
120	31	34·5	32·75
125	30	33·5	31·75
130	28·5	34·5	31·5
135	28	33	30·5
140	26	31	28·5
145	23	30	26·5
150	21·5	26·5	24
155	18	25·5	21·75
160	14·5	20	17·25
165	10	16	13
170	6	6·5	6·25
175	4	1·5	2·75
180	0·5	0	0·25
	P = 48	P = 45	

Table IV.

Faraday cylinder fixed at 90°.
Readings taken with Reflector at different angles from 90° to 180°.

Reflector.	First series deflection.	Second series deflection.	Mean deflection.
	P = 52	P = 53	
90°	+0·5	0	+0·25
95	0	0	0
100	0·5	0·5	0·5
105	1	1	1
110	3·5	2·5	3
115	7	3·5	5·25
120	11	7	9
125	18·5	10	14·25
130	21·5	12	16·75
135	23·5	14	18·75
140	24·5	14·5	19·5
145	24	14	19
150	22	13·5	17·75
155	18·5	13	15·75
160	15	12	13·5
165	11	11·5	11·25
170	5	6·5	5·75
175	3	2·5	2·75
180	0·5	0·5	0·5
	P = 44	P = 44	

Table V.

Faraday cylinder fixed at 112·5°.
Readings taken with Reflector at different angles from 112·5° to 180°.

Reflector.	First series deflection.	Second series deflection.	Mean deflection.
	P = 46	P = 41	
112·5°	+0·5	+1	+0·75
115	+0·5	+0·5	+0·5
120	0	0	0
125	1	3	2
130	6	16	11
135	18·5	26·5	22·5
140	27·5	45	36·25
145	29	51	40
150	32	54	43
155	31	52	41·5
160	27·5	47	37·25
165	20	39	29·5
170	11	11	11
175	2	0	1
180	0	+0·5	+0·25
	P = 48	P = 32	

Table VI.

Faraday cylinder fixed at 135°.
Readings taken with Reflector at different angles from 135° to 180°.

Reflector.	First series deflection.	Second series deflection.	Mean deflection.
	P = 54	P = 50	
135°	3	2	2·5
140	2	1	1·5
145	26	10	18
150	28·5	62	45·25
155	50	64	57
160	46	64	55
165	44	66	55
170	30	70	50
175	29	19	24
180	27	9	18
	P = 62	P = 47	

Table VII.

Reflector stationary at 67·5°.
Readings taken with Faraday cylinder at different positions from 67·5° to 247·5°.

Cylinder.	First series deflection.	Second series deflection.	Mean deflection.
	P = 40	P = 55	
67·5°	+1	+0·5	+0·75
60	+0·5	0	+0·25
50	2	1	1·5
40	9	5·5	7·25
30	17·5	10	13·75
20	22	12	17
10, 0, 350	Cylinder interfering with primary cathode rays.		
340	37	24·5	30·75
330	42	28	35
320	44	30	37
310	44	31	37·5
300	40·5	31	35·75
290	33	28	30·5
280	24	22	23
270	15	10	12·5
260	2	0·5	1·25
250	0	+0·5	+0·25
247·5	+0·5	+0·5	+0·5
	P = 47	P = 47	

Table VIII.

Reflector stationary at 90°.
Readings taken with Faraday cylinder at different positions from 90° to 270°.

Cylinder.	First series deflection.	Second series deflection.	Mean deflection.
	P = 46	P = 55	
90°	0	0	0
80	0·5	0·5	0·5
70	3	1·5	2·25
60	19·5	4·5	12
50	26	10	18
40	32	13	22·5
30	32	14·5	23·25
20, 10, 0, 350, 340	Cylinder interfering with primary cathode rays.		
330	28	21	24·5
320	26	20·5	23·25
310	22	19	20·5
300	16	20	18
290	8	10	9
280	1	1	1
270	0	0	0
	P = 49	P = 47	

Table IX.

Reflector stationary at 135°.
Readings taken with Faraday cylinder at different positions from 135° to 15°.

Cylinder.	First series deflection.	Second series deflection.	Mean deflection.
	P = 43	P = 51	
135°	+1	0	+0·5
125	4	2	3
115	20	22	21
105	33	31	32
95	38·5	38	38·25
85	55·5	41	48·25
75	40	43·5	41·75
65	37·5	43·5	40·5
55	37·5	43	40·25
45	35	41·5	38·25
35	32	39	35·5
25	29·5	35	32·25
15	22	24·5	23·25
	P = 53	P = 47	

The above are a few typical examples of a much larger number of sets of observations, all giving similar results. On examination it will be seen that in all, both in the cases when the reflector was moved so as to reflect the cathode rays at different angles into the stationary Faraday cylinder, and also when the reflector was stationary and the field of reflected rays explored by moving the cylinder, the effects are approximately similar. In each case the electric charge imparted to the cylinder, as measured by the electrometer deflection, is greatest for almost exactly those positions of reflector and cylinder relatively to the primary cathode rays that would make the angle of reflection most nearly equal to the angle of incidence, the electrometer deflections diminishing gradually, though not at a uniform rate, the greater the departure from this condition. Any slight discrepancies are readily accounted for by the difficulties of maintaining a constant vacuum and uniform action of the induction coil contact breaker, and are also possibly, in some instances, due to electrostatic repulsion experienced by the reflected cathode rays. It would, therefore, appear that the reflection of cathode rays by a flat polished platinum surface is not altogether diffuse, but takes place to some considerable extent in a more or less specular manner.

As will be observed in several of the sets of observations, a small reverse deflection of the electrometer, indicating a slight positive charge of the cylinder, was obtained either at the end or beginning of a series, when the relative positions of reflector, cylinder, and primary cathode rays would allow of no reflected cathode rays entering the cylinder. This curious fact requires further investigation.

In order to ascertain whether the intensity of the reflected cathode rays would increase as the incidence was made more slanting, several series of observations were made, where both the reflector and cylinder were moved, the latter at twice the rate of the former, in such a manner as to measure the maximum intensity of the reflected rays for varying angles of incidence. The following table (Table X) gives the mean deflections obtained with four series, which appear to show that the intensity of the reflected rays does increase as the incidence is more slanting. The increase in the early stages is not, however, great; while it is possible that in the latter stages some direct cathode rays obtained access to the cylinder.

Charge Imparted to the Reflector.

Experiments were also made to ascertain whether the charge imparted to the reflector varied with the angle of incidence of the primary cathode rays. The results are given in Table XI, from which it will be seen that the electrification of the reflector while strongly negative for normal incidence of the cathode rays, becomes zero at an angle between 130° and 135°, and slightly and increasingly positive for still larger angles. Comparing this result with that obtained in the pre-

Table X.

Both Reflector and Cylinder moved, the latter at twice the angular rate of the former.

Reflector.	Cylinder.	Mean deflection.
100°	20	25·875
105	30	28·375
110	40	29·375
115	50	29·5
120	60	29·75
125	70	29·75
130	80	30·25
135	90	30·875
140	100	32·25
145	110	36·75
150	120	43·25
155	130	52·125
160	140	64·375
165	150	79·125

ceding experiment given in Table X, it will be noted that as the negative charge imparted to the reflector diminishes the maximum charge conveyed by the reflected cathode rays increases, though the rates of diminution and increase respectively are by no means equal.

Table XI.

Reflector connected to electrometer.

Reflector.	First series deflection.	Second series deflection.	Mean deflection.
90°	76	35	55·5
95	72	33·5	52·75
100	71	31	51
105	63	27	45
110	50	24	37
115	37	15	26
120	23	11·5	17·25
125	13	7	10
130	4	4	4
135	+1	0·5	+0·25
140	+2·5	0	+1·25
145	+3	0	+1·5
150	+3	0	+1·5
155	+3	0	+1·5
160	+3·5	0	+1·75
165	+4	+0·5	+2·25
170	+5	+1	+3

The writer has previously described* how with an anticathode, inclined at an angle of 45° to the axis of a conical cathode stream, he found, by examination with a pin-hole camera, that those portions of the stream which impinge most normally upon the anticathode are the most efficient in producing Röntgen rays, while those portions of the stream which strike the anticathode surface very much on the slant are less efficient in producing Röntgen rays. There is probably some connection between this and what is indicated in Tables X and XI. The fact that the more normal is the angle of incidence, the greater is the amount of negative charge imparted to the anticathode reflector, the greater the amount of Röntgen rays produced, and the less the amount of charge in the reflected cathode rays, would seem to support the view that the Röntgen rays are actually generated in some way by the electric charges carried by the cathode ray particles being imparted to the anticathode.

Conclusion.

The results of the experiments described above differ in at least one important particular from those obtained by Mr. H. Starke, an account of whose researches appeared in Wiedemann's 'Annalen,' No. 9, p. 56, 1898, while the writer's investigatons were in progress. Mr. Starke, using a form of tube in which the arrangement of cathode, anode, and reflector was very similar to that shown in fig. 9, but with a Faraday cylinder fixed in one definite position, as in the tube illustrated in fig. 2, and using the galvanometer method of measuring the charge conveyed to the cylinder by the reflected cathode rays, appears to have found that so long as the same face of the reflector was turned towards both the cathode and cylinder, the orientation of the reflector did not affect the amount of charge conveyed to the cylinder. This is so totally at variance with the results given above, which were repeated over and over again, that the writer can only assume that the methods employed by Mr. Starke were not as sensitive as his own, particularly as in the case of the writer's results those obtained by rotating the reflector, with the cylinder stationary, are confirmed by those obtained with a stationary reflector and a movable cylinder—the latter method not having been employed by Mr. Starke.

In conclusion, the writer desires to express his great indebtedness to the valuable assistance of Mr. J. C. M. Stanton and Mr. H. L. Tyson Wolff in carrying out the above investigations.

* 'Roy. Soc. Proc.,' vol. 63, pp. 434–5.

FIG. 1.

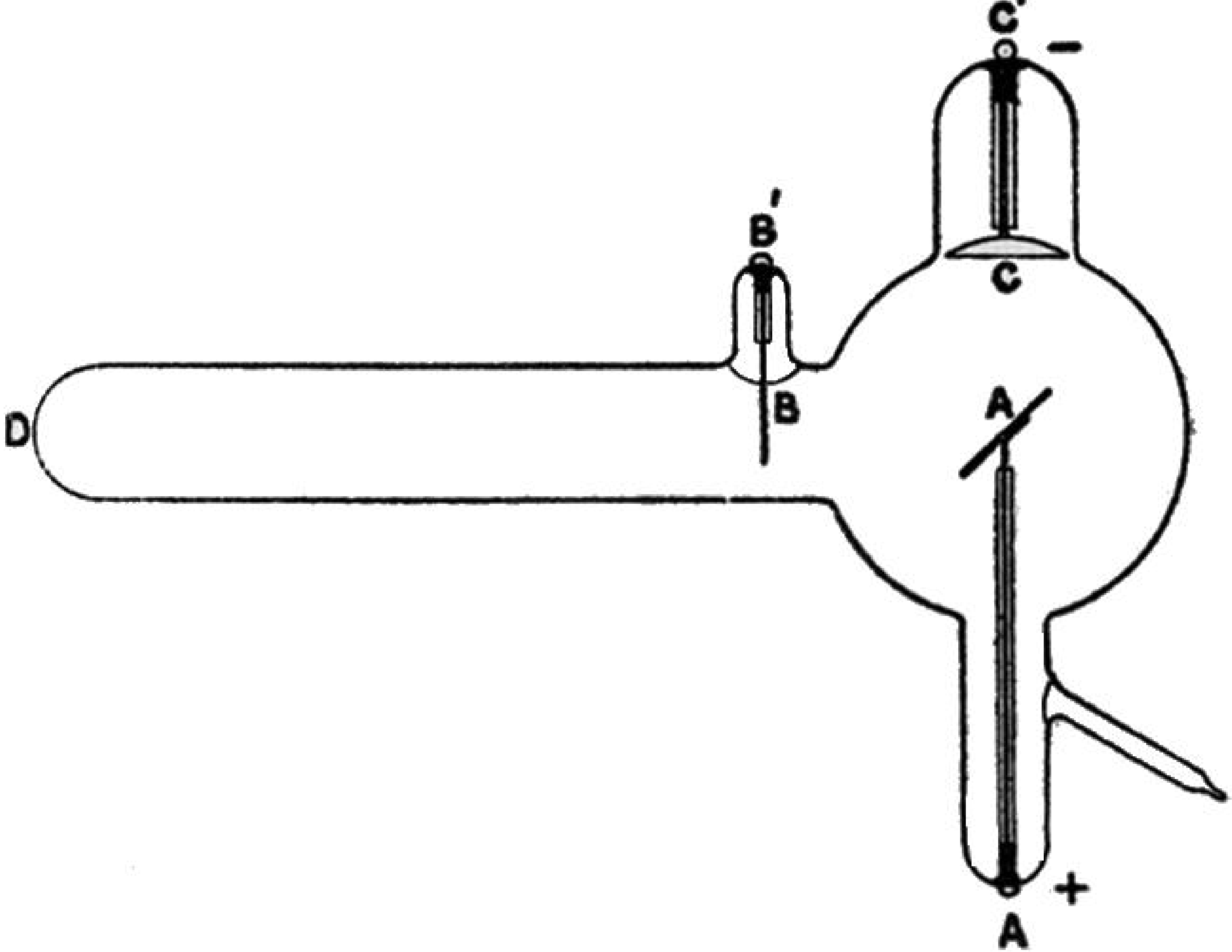


FIG. 2.

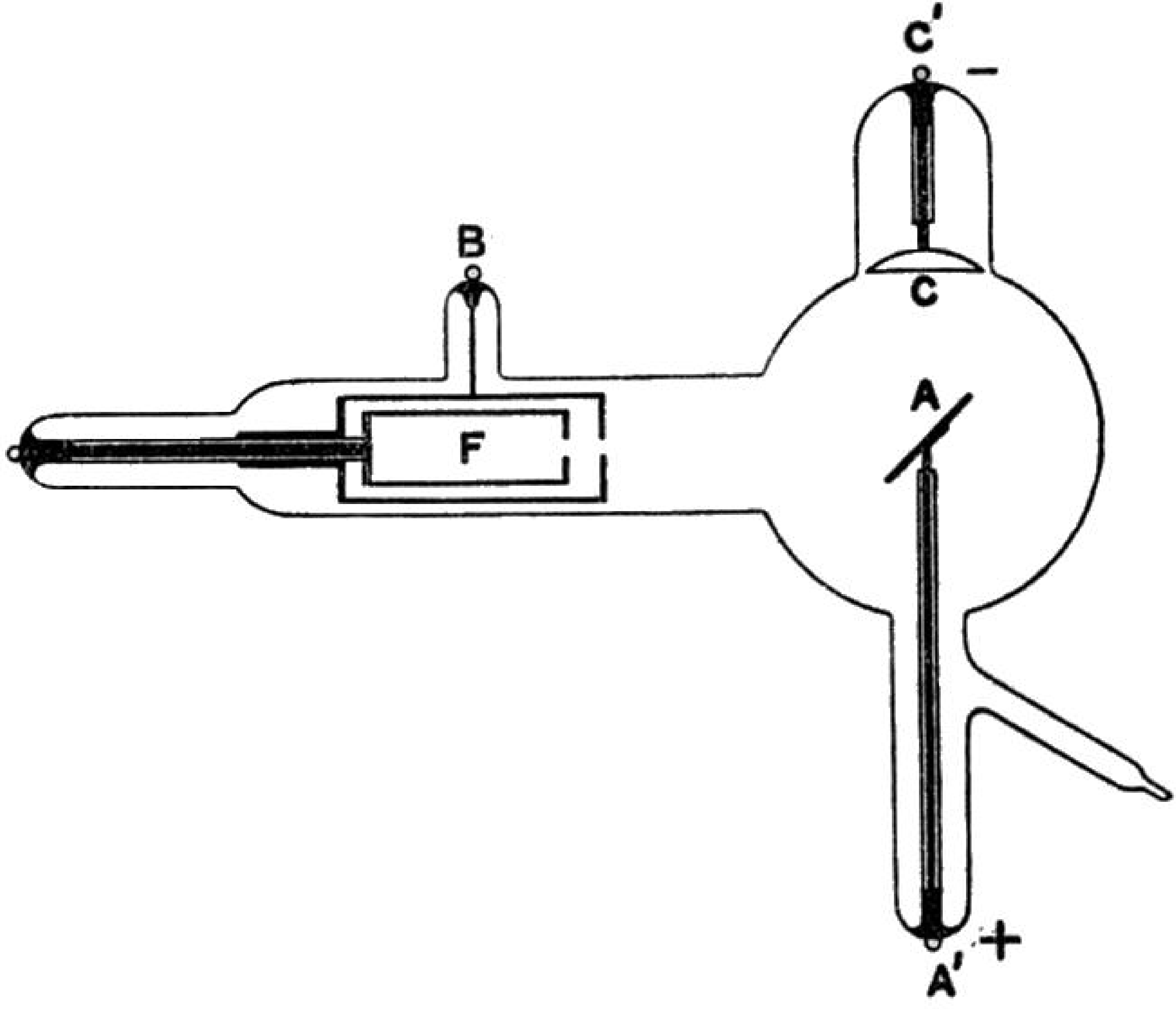


Fig. 3.

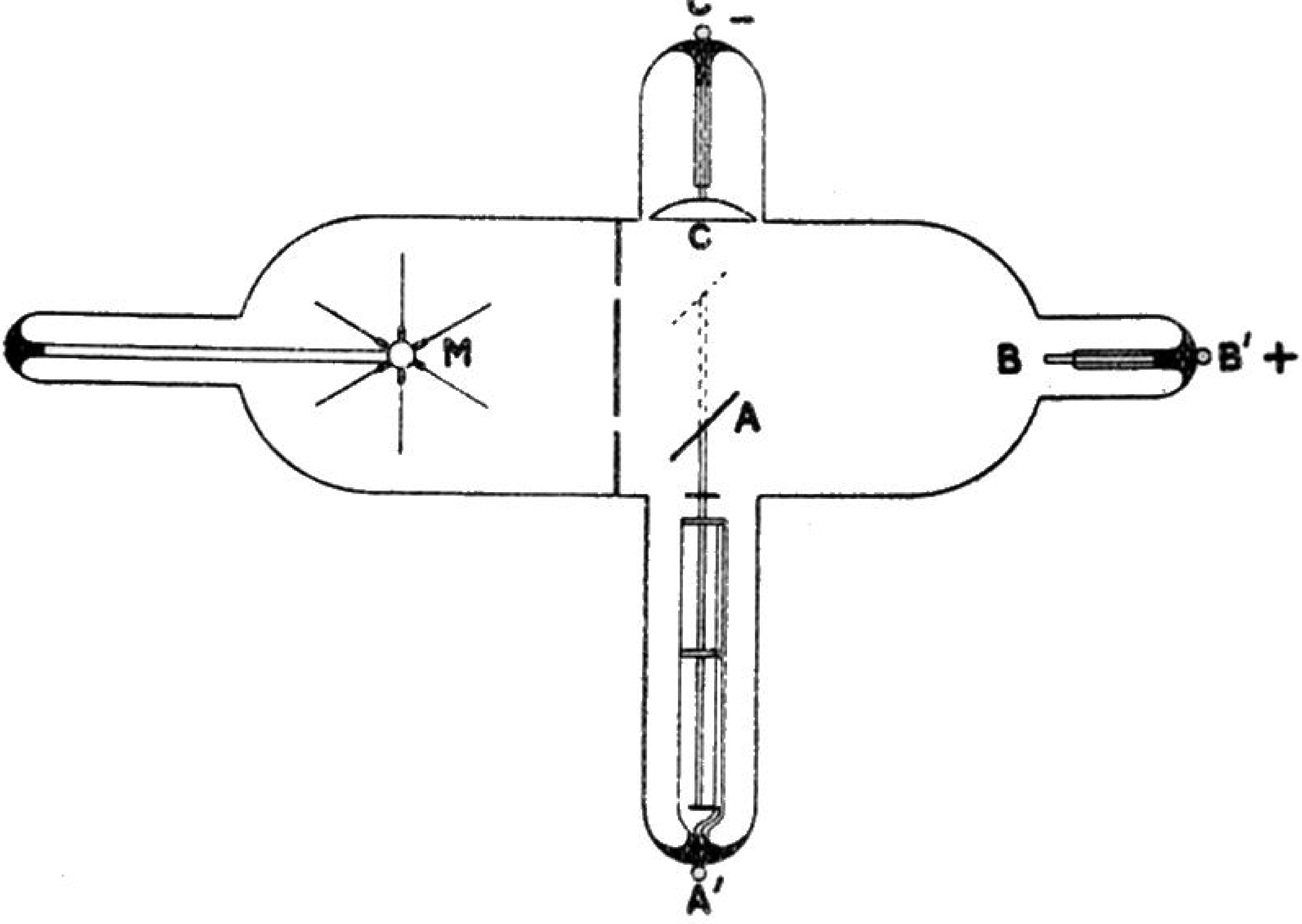


FIG. 4.

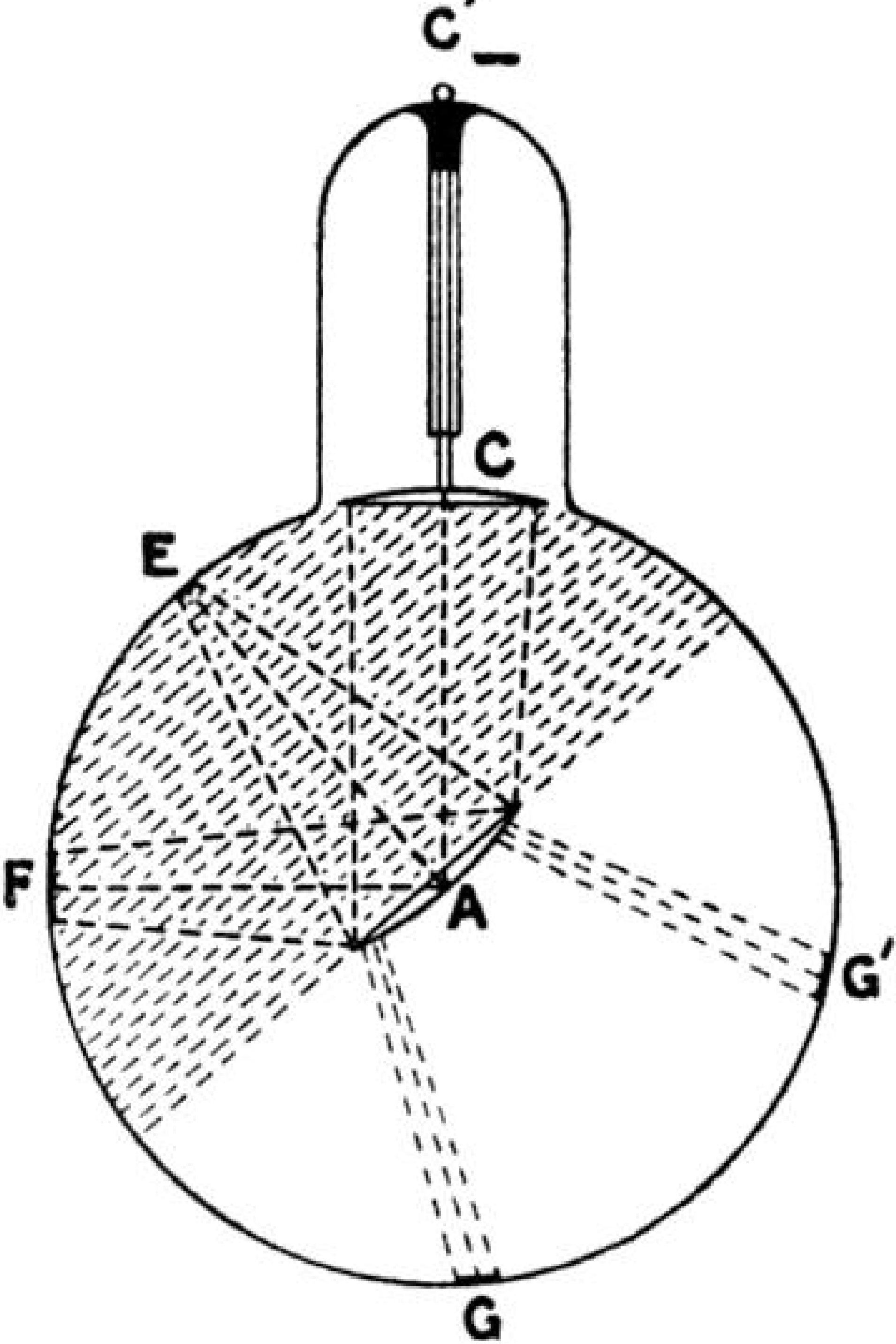


FIG. 5.

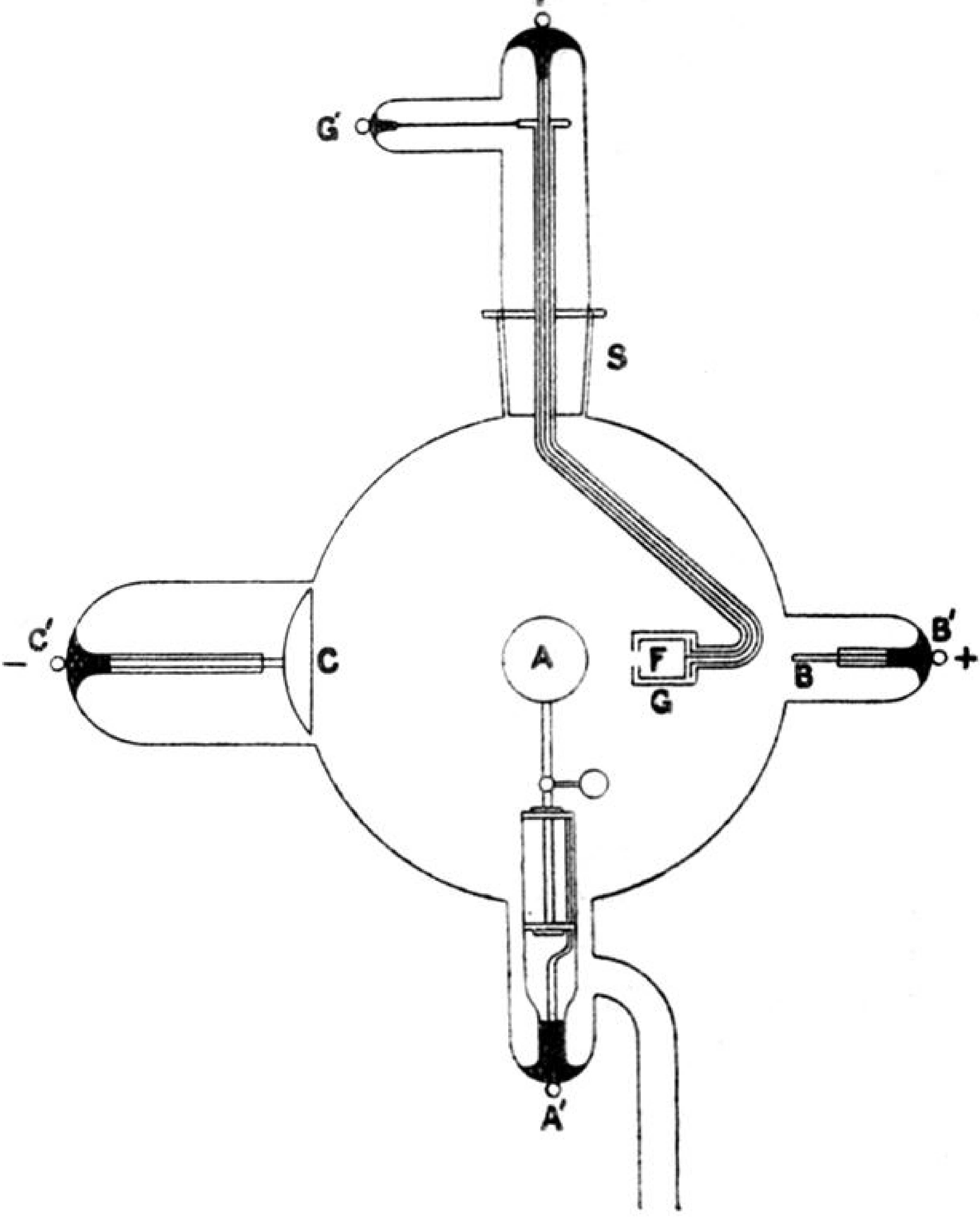


FIG. 7.